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A Context-Based Requirements Analysis Method for PSS Design

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Abstract

Focusing on the importance of considering value-in-context, this research aims to formalize how the concept of context should be handled in Product-Service Systems (PSS) design. In PSS design, it is important to combine products and services appropriately based on customer requirements. For the requirements analysis, specific situations in product use should be clarified considering customer context. However, there is no method to extract elements of customer context in existing PSS design methodologies. This paper proposes a framework which classifies viewpoints for extracting the elements of context. Based on the framework, a context-based requirements analysis process is also proposed.

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Keywords: PSS design; Value-in-context; Requirement analysis.

1. Introduction

Recently, servitization of manufacturing has attracted much attention from both industrial and academic sides as a key to realizing competitive and sustainable businesses [1]. In order to support a smooth transition towards servitized business, many authors have addressed the development of design methodologies for product-service systems (PSS), which are a business concept characterized by the integration of products and services [1-3]. In the design of PSS, it is important to combine products and services appropriately according to customer requirements occurring in product/service use.

Vargo and Lusch, who proposed service-dominant logic in marketing research, have emphasized the importance of considering "value-in-context" to realize servitized businesses in manufacturing companies [4]. Value-in-context can be regarded as a way of thinking that the value of a product is determined by customers, depending on their own contexts of using the product [4, 5]. Customers therefore require different values in response to changes in their contexts. Services will become a means of responding to the change in required values. PSS design should be conducted considering such customer contexts in product/service use. However, in existing PSS design methodologies, the concept of context is implicitly handled, and its role in PSS design has not been defined clearly. This obstructs the deeper and broader analysis of customer requirements to explore new business opportunities.

From this background, this research aims to formalize how the concept of context should be handled in PSS design. This paper proposes a framework which classifies viewpoints for extracting specific elements of context which influence customer requirements for PSS. Based on the framework, a context-based requirements analysis process is also proposed in this paper. The proposed process was applied in a PSS design workshop held in a manufacturing company.

This paper is organized as follows: Chapter 2 explains existing methods for customer requirement analysis and remarks upon the scope of this paper. In Chapter 3, the concept of context in this research is defined based on related studies. Additionally, elements of context are classified.

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Chapter 4 proposes a process of requirements analysis based on customer contexts. In Chapter 5, the results of the application are mentioned. Chapter 6 discusses the effectiveness and remaining issues of the proposed method. Chapter 7 concludes the paper.

2. Literature review

2.1. Requirements analysis for PSS design

A PSS can be defined as an integrated product and service offering that satisfies customer requirements occurring in aftersales phases [2]. Requirements analysis has therefore been recognized as one of the important issues in PSS research. Cavalieri et al. argued that the phases most lacking in existing studies are requirements identification and testing [1].

As one of the particular PSS design methodologies, Aurich et al. proposed a life cycle-oriented design of PSS [6]. On the part of technical service design in particular, they proposed identification of customer demands as the first step without describing a systematic process. Morelli proposed a model for PSS design project evolution which includes market analysis and use-case analysis as two steps; in the use-case analysis particularly, a set of items such as flow of events, pre-conditions, and post-conditions is used to describe the use case [7]. Functional requirements are argued to be deduced from the iteration of several use cases. Shimomura et al. structured a set of templates which enables designers to identify customer requirements in a systematic procedure [3]. The templates include the concept of persona and scenario which were originally proposed in software engineering [8]. A persona represents an image of the customer by detailed descriptions about his/her personality, lifestyle, activity cycle, etc. A scenario is like a short novel in which experiences of the persona with product/service use are written in natural language. Customer requirements are identified from the keywords in the described scenarios.

2.2. Scope of this paper

In the research on service-dominant logic [4, 5], the importance of considering value-in-context has been emphasized. While the concept of value-in-context has not been concretely defined, Chandler and Vargo mentioned that contexts can be regarded as a unique set of actors and the unique reciprocal links among them [5]. In other words, the authors indicated that the values of the customer depend on relationships with other actors.

In the requirements analysis methods mentioned in 2.1, customer contexts are not clearly handled by designers. For example, the persona and scenario partially include elements of context such as customer attributes and situations in product/service use. However, there is no framework which enables designers to extract elements of context from various points of view. This can narrow the range of context reflected in described personas and scenarios. To solve this issue, this paper proposes a framework which classifies viewpoints for extracting specific elements of context which influence customer requirements for PSS. By using this framework, this paper extends the requirement analysis process proposed in ref. [3] to handle value-in-context.

3. Definition and classification of contexts

Whereas the concept of context has been studied in various research fields, there is no commonly accepted definition for it. With respect to some studies (e.g. [9-12]), the concept of context can be regarded as environments and situations where person-to-person, -product, or -computer interactions are conducted. This standpoint is common, especially in linguistic and human-computer interaction research. By simplifying the terms “environment” and “situation”, this paper defines context as *a set of spatial-temporal elements related to the person or product*. In addition, these spatial and/or temporal elements are called *contextual elements* in this paper.

This definition allows an extremely wide range of elements to be handled as a part of context. Because it is not realistic that PSS designers exhaustively consider every contextual element in the PSS design process, this study provides several viewpoints from which to consider and extract contextual elements that strongly influence customer requirements. Figure 1 shows a framework which classifies contextual elements related to a certain customer into four quadrants with two axes. The vertical axis means the change cycle of elements: long-term vs. short-term. The horizontal axis divides elements with respect to where the elements are embedded: individual vs. global. These axes were structured through reviewing literature in various research fields. The remainder of this chapter explains the details of each quadrant.

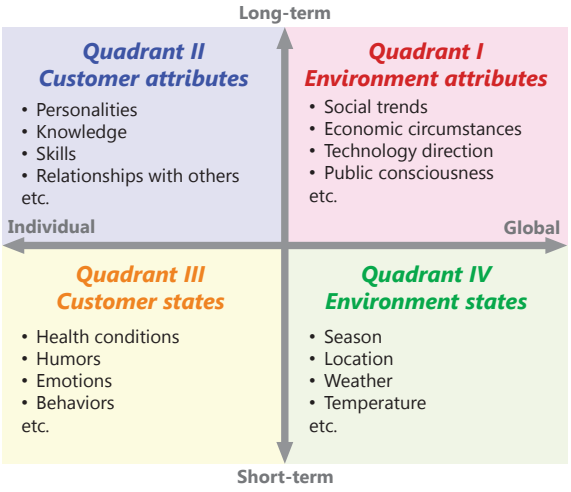

Fig. 1. Four quadrants of contextual elements

• *Quadrant I: Environment attributes*

Quadrant I consists of contextual elements embedded in the environment around the customer; these have a relatively long-term change cycle. This quadrant is composed of macro environmental elements, e.g., social trends, economic circumstances, technology direction, and so on. Such

elements indirectly influence the fundamental values of the customer. PSS designers should clarify these elements when it is difficult to identify the fundamental values of their customers, for instance, in cases of targeting foreign or future customers.

• *Quadrant II: Customer attributes*

Elements in Quadrant II are strongly dependent on the experiences of the customer; these vary relatively slowly. For example, customers' knowledge, skills and relationships with others are classified into this quadrant. These elements directly contribute to forming the fundamental values of the customer.

• *Quadrant III: Customer states*

Quadrant III includes elements depending on the customer; these have a relatively short-term change cycle. Health conditions, emotions, and behaviors of the customer are sorted to this quadrant. This type of element shapes a concrete situation in product/service use and influences specific requirements.

• *Quadrant IV: Environment states*

Contextual elements in Quadrant IV are embedded in the environment around the customer; these vary at all times. This quadrant is composed of elements such as season, location, weather, and so on. These elements also shape a concrete situation in product/service use.

4. Context-based requirements analysis process

4.1. Overview

According to the definition and classification of context mentioned above, this paper extends the requirement analysis process proposed in [3] to consider value-in-context clearly. Figure 2 illustrates an overview of the extended process. The blue boxes in this figure represent added tasks for clarifying customer contexts.

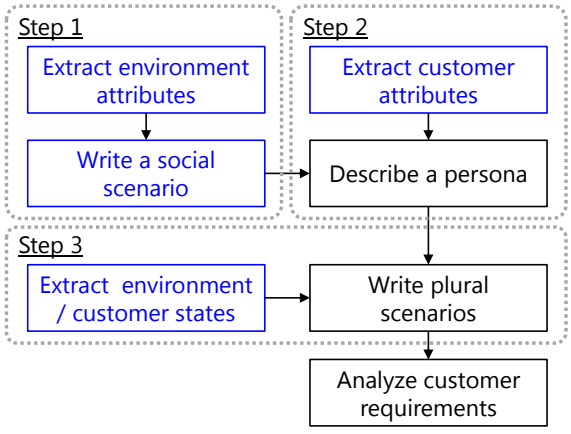

Fig. 2. Extended requirements analysis process

In this process, the contextual elements in Quadrants I and II are regarded as invariables. Based on these elements, designers define a social scenario (Step 1) and a persona (Step 2). Meanwhile, the elements in Quadrants III and IV are considered variables. Designers select some subsets of these elements to specify concrete situations in product/service use. Then they write scenarios based on each concrete situation (Step 3). By analysing the described scenarios, designers can identify customer requirements occurring in different contexts. In this chapter, Steps 1–3 are explained by using an example case. The example case is a future PSS using automotive information device targeting for elderly people.

4.2. Step 1: Clarify a macro environment

The goal of this step is to clarify a macro environment around the core product/service and the customer by using contextual elements in Quadrant I. This step is very important in cases of targeting foreign or future customers, because in these cases, each designer potentially has a different perspective of the world.

Designers first extract specific contextual elements from the environmental information. For the extraction, PEST analysis (political, economic, social and technological analysis) [13] is useful. Table 1 shows an example of the extracted elements using PEST analysis. After the extraction, designers write a social scenario in natural language by configuring the extracted elements. As shown in Table 2, a social scenario includes the momentum of fundamental values in this world.

Table 1. A part of PEST analysis to extract contextual elements in Quadrant I

S: Society
・Promotion of supporting elderly people ・Development of infrastructures for wheelchair users ・Popularization of communication devices
T: Technology
・Development in Lifelog input station ・Development in information technology for collecting large amount of human activities

Table 2. An example of social scenario

Title: Life of elderly people 10 years from now
Popularization of electric wheelchair expands the range of elderly people, and they have begun to go out actively. This raises the demand for comfortable and enjoyable transportation. Moreover, this situation stimulates them to communicate with other people in their cities. As a result, many communities have been created around them. On the other hand, the accident rate has increased with the increasing opportunities of elderly people to go out. Their families have therefore come to feel insecure about their outings.

4.3. Step 2: Clarify an image of the customer

In this step, first, designers determine the attributes of the customer, that is, the contextual elements in Quadrant II. As mentioned in 2.2, contexts can be created by reciprocal links with others. Both internal and external elements are thus extracted in this step. Internal elements include the unique knowledge, skills, experiences and preferences of the customer. External elements mean relationships with

surrounding products, services, people and organizations. Some of these elements can be imagined from the social scenario described in Step 1. Others need to be defined by referring to data related to the customer. Based on the extracted contextual elements, a persona is constructed to fix an image of the customer (Fig. 3).

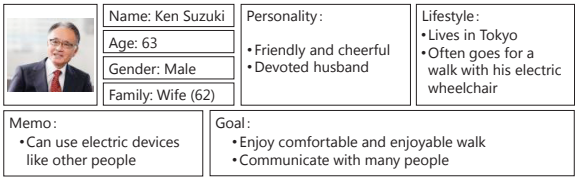

Fig. 3. An example of persona description

4.4. Step 3: Clarify concrete situations in product/service use

This step aims to specify different plural situations in product/service use. To do this, first the contextual elements in Quadrant III and IV are extracted. In this study, a worksheet is developed to support the designers in finding and organizing contextual elements. This worksheet (see Fig. 4) is partitioned with respect to several viewpoints: psychological and physical states for Quadrant III and time, place and occasion for Quadrant IV. According to these viewpoints, designers explore specific contextual elements. An element in Quadrants III and IV can be represented as a variable and its possible values. For example, for the variable, "humor", which was extracted as a psychological state of the customer, it is possible to have a value of either "good" or "bad".

Quadrant	III. Customer states		IV. Environment states		
Viewpoints	Psychological state	Physical state	Time	Place	Occasion
Contextual elements	**Humor:** Good / Bad	**Health condition:** Good / Getting a cold **With whom:** No one / With wife / With a friend	**Time:** Morning /Afternoon **Season:** Spring / Summer	**Road type:** Flat / Slope / Stairs **Forward visibility:** Good / Poor	**Weather:** Sunny / Cloudy / Rainy

Fig. 4. A worksheet for extracting contextual elements in Quadrant III and IV

Designers select a subset of valuables with a certain value to specify a concrete situation in product/service use, and then they write a scenario. Figure 5 shows a selected subset of contextual elements and the scenario written based on the subset. The variable values considered in this subset are colored red. This scenario therefore represents a situation that consists of the following elements: it was a sunny afternoon; the customer was going out without anyone; the forward visibility of the road was poor. If any of these elements were to vary, the situation would change significantly. For instance, if the forward visibility was good, the customer would not get into the danger described in Fig. 5.

To consider multiple scenarios, designers specify plural situations which are constructed by different subsets of contextual elements. By analysing the created multiple scenarios, designers identify a variety of requirements for the PSS.

Selected context		Scenario
Weather: Sunny / Cloudy / Rainy	**With whom:** No one / With wife / With a friend	1 PM. Today, my wife is going out with her friend. I don't have all that much else to do; let's start off a ramble. I want to find a new interesting place. ... Hmmm, this is a blind corner. How I hate it. "Screeeech!!!" Oh, what did I say? I am concerned about avoiding injury
Time: Morning / Afternoon	**Forward visibility:** Good / Poor	

Fig. 5. A selected subset of contextual elements and their scenario

5. Application

5.1. PSS design workshop

To verify the effectiveness of the proposed requirements analysis method, we organized a PSS design workshop in a Japanese manufacturing company. This workshop involved 24 participants. They had different jobs (e.g. engineer, researcher and manager) and specialties (e.g. information technology, infrastructure, heavy machinery and so on) in their usual work in the company. We divided them into five design teams, considering the balance of their specialties.

The goal of the workshop was to design a future innovative PSS considering value-in-context. Because of time limitations, each design team conducted only two phases of PSS design: requirements analysis and functional design. At the beginning of the workshop, each team set a core product and target customer (Table 3). As shown in Table 3, both the business-to-business (B2B) and business-to-consumer (B2C) cases were addressed in the workshop.

Table 3. Core products and target customers in the workshop

Team	Core product	Customer	
A	Monitoring camera	Convenience store in Africa	(B2B)
B	Smartphone	Female international student	(B2C)
C	Car navigation system	Taxi company	(B2B)
D	Plastic bottle	Beverage manufacturer	(B2B)
E	Refrigerator	Elderly woman	(B2C)

5.2. Results of requirements analysis in the workshop

In the phase of requirements analysis, the proposed process and tools mentioned in Chapter 4 were used by the participants. Every team spent approximately two and a half hours on the group work to analyse customer requirements using our method. In this section, the summary of requirements analysis in team C is mentioned as an example.

In Step 1, based on some contextual elements, they described a social scenario as follows: the performance of public transportation has been weakened by the population decrease in Japan; on the other hand, there have been growing demands by elderly people for easier ways to go out. Based

on such a macro environment, in Step 2, a taxi company which offers additional services in support of elderly people was set as the customer of team C. As a persona, a driver of the taxi company was illustrated (see the left picture of Fig. 6). Next, by using the worksheet mentioned in 4.4 (see the right picture of Fig. 6), they clarified considerable contextual elements about the customer and environment states. After selecting subsets of these elements, they developed two scenarios (A and B). Scenario A was based on the following situation: the driver is going to pick up his regular customer; he is feeling pressed, because this is an urgent request. Scenario B described a case where his customer is not regular; nor is the request urgent. With respect to the two scenarios, they identified physical, informational and psychological requirements for the PSS (Table 4).

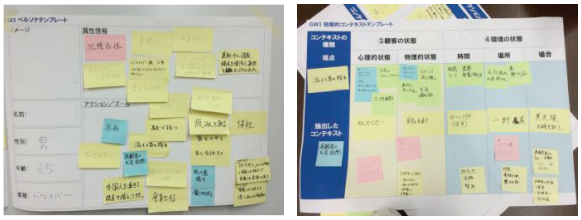

Fig. 6. The described persona and worksheet for extracting short-term contextual elements (in Japanese)

Table 4. Identified requirements

Scenario	Identified requirements
A	・ Enable easy discernment of urgency of request ・ Let a driver know the shortest path ・ Display the condition of the customer
B	・ Let a driver know detailed information about a new customer ・ Make a driver feel a meaningful benefit, offering additional services for supporting customers

5.3. Questionnaire survey

After the workshop, we conducted a questionnaire survey to identify the effectiveness and remaining issues of the proposed method. Table 5 lists all items of this questionnaire. In the questionnaire, we asked all of the participants to compare the proposed method and other methods used in their usual work, with respect to result, process and tools. The rest of this section explains results of the questionnaire.

Table 5. Questionnaire items

No.	Question
Q1	How do you usually analyse customer requirements in your company/division/projects?
Q2	How do you feel about the results of the requirement analysis in this workshop? If possible, please answer this comparing with the method answered in Q1.
Q3	How do you feel about the process and tools of requirement analysis in this workshop? If possible, please answer this comparing with the method answered in Q1.

Table 6 summarizes the answers to Q1 and the quantity of responses for each. With the exception of the answer that there is no definite method, the most common answer was a direct interview with customers. Other answers included discussion/brainstorming, questionnaire survey and data mining. Only one participant usually used the traditional persona method.

Table 6. Answers to Q1 (except for no answer)

Answers	
No definite method	6
Direct interview with customers	4
Discussion/brainstorming among project members	2
Satisfaction survey by questionnaire	2
Analysis of market research report	1
Persona method	1
Data mining	1

In Q2, we asked participants to evaluate the results of the requirements analysis. Basically positive answers were obtained. The following are representative answers:

- Reasonable results could be obtained by following the process in the workshop.
- It was really interesting that completely different requirements could be identified by changing the selection of context elements.
- By describing an image of a specific customer and his/her scenarios, real requirements could be acquired. However, I wonder if we can capture mass needs and requirements by using this method.
- In this workshop, we handled an imaginary case. I would like to apply the method used in the workshop to my actual work.

Additionally, Q3 inquired about the evaluation of the process and tools used in the workshop. From the evaluations, we could find both the effectiveness and the remaining issues regarding the proposed process and tools. A summary of participants' evaluations is as follows:

- The way of thinking in this process was novel and effective in deeply considering situations of customer.
- The requirements analysis process was well organized, something that has not been systematized in our company.
- The worksheet for extracting contextual elements of the customer and environment states (mentioned in 4.4) was useful to manifest our tacit knowledge.
- The level of importance and priority of information could be determined in the process. This would provide a benefit to avoid wavering in the entire design process.
- It was still subjective to make a choice of what information should be used or not.
- While the viewpoints given by the tools were effective in deriving a lot of ideas easily, these restricted our creativity.
- In this workshop, we used paper-based tools. It was uncomfortable, because we had to handle many sticky notes. I prefer to use computer-based tools.

6. Discussion

6.1. Effectiveness of the method

From the positive responses in the questionnaire, the effectiveness of the proposed method could be confirmed. By providing the viewpoints and process by which to extract various contextual elements for designers, this method realized the formalization of context-based requirements analysis for PSS design. It could be said that this method is effective as an engineering method, because such viewpoints and processes have not been formalized in an actual company.

In the workshop mentioned in Chapter 5, some teams addressed B2B cases, and the others dealt with B2C cases. We obtained positive responses from both sides. The proposed method is therefore applicable to both B2B and B2C cases. Meanwhile, there was an opinion from a participant that some terms used in the tools were not suitable for handling B2B cases. To improve the usability of the method, tools specialized for B2B cases will be necessary.

In the questionnaire, there are several responses that the proposed method is effective for deeply considering situations of the customer. Most such responses were given by participants who usually conducted direct interviews with their customers. This result can be interpreted to mean that direct interviews can possibly lead to a superficial understanding of customers and their situations. In contrast, this method has the benefit that designers can image customers and their situations from a variety of angles by changing contextual elements.

6.2. Remaining issues

The questionnaire also revealed some remaining issues. The first one is subjectivity in making a choice of what information should be used or not. Excluding the subjectivity of designers is not easy, but criteria for selecting information will be necessary to realize a more subjective requirements analysis. The second issue is a trade-off between easiness and variety in idea generation. The provision of viewpoints enables designers to facilitate their idea generation, but these also restrict their creativity. To solve this issue, we need to develop a way to stimulate designers moderately to generate ideas from viewpoints that are not provided by the tools. The last issue was about paper-based tools. Whereas such paper-based tools are suitable for collaboration in a design team (e.g. [14]), computer-based tools are appropriate in cases where designers must handle many objects. The authors of this paper have developed a CAD system for PSS design (e.g. [15, 16]). Future studies should include the implementation of the proposed method using such a CAD system.

There is also the remaining issue of the definition and classification of context and its elements mentioned in Chapter 3. The method proposed, based on the definition and classification, was useful. However, the completeness and validity of the definition and classification themselves has not been verified in this research. Future work should therefore include a survey to verify the definition and classification of context.

7. Conclusion

Focusing on the importance of considering value-in-context, this paper aimed at the formalization of a way in which the concept of context should be handled in PSS design. This paper proposed a framework which classifies viewpoints for extracting specific contextual elements which influence customer requirements for PSS. Based on the framework, the context-based requirements analysis process was also proposed in this paper by extending the existing persona and scenario method. The proposed requirements analysis method was applied in a workshop. The effectiveness and remaining issues of this research were discussed mainly based on the questionnaire obtained in the workshop.

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